Investigation Of Aerobic Degradation Of Industrial Wastewater Containing High Organic Matter: Kinetic Study

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Abstract

Aerobic biodegradability of the industrial wastewater (IW) containing high level of COD was assessed in laboratory-scale batch reactors. Two experimental runs were carried out at a ratio of substrate-to-microorganisms concentration S_o/X_o equal to 0,5 and 3,5 g COD /g MLVSS while equal to 1 ratio of synthetic wastewater to IW. Chemical oxygen demand, pH, and alkalinity were determined during the experiments. An increase in the influent substrate concentration not caused a decrease in COD removals at similar times of working. Since the inoculum was previously acclimatized to COD concentration, a substrate (mixture of the synthetic and industrial wastewater) inhibition at the higher concentrations of COD most probably was absent. It was found that a first-order kinetics adequately described the variation of COD removal with time. The values of the first-order reaction constants were found to be 0,3083 and 0,2038 d^{-1} for Runs 1–2, respectively.

Keywords: Industrial wastewater, activated sludge, aerobic treatment, COD removal, first-order kinetic model

Introduction

Some industrial wastewaters have complex mixtures. Such mixtures render of wastewaters potentially toxic to the environment. One solution to the disposal problem is on-site biological treatment of such wastewaters, using bioreactor systems.

Hardly any attempts have been undertaken to imply biological methods to industrial wastewater treatment without prior physical-chemical splitting. Biological treatment offers an alternative solution. Aerobic biological treatment processes can successfully degrade simpler and more

bioavailable constituents of this type complex wastewater, leaving behind complex recalcitrant, and potentially toxic organic compounds. These toxic components of the waste typically persist after biological treatments and thus have to be further treated in order to enable safe disposal, which can add additional costs.

The study was assessment treatability of an industrial wastewater contain high organic matter (mixture of biodegradable substance and small amount of non-biodegradable substance). The aim of this research was to develop a biotechnological method for industrial wastewaters containing high organic matter. Especially this level COD contain industrial wastewaters such as textile dye industry, meat processing industry, cheese whey, milk industry, pulp and paper industry, oily wastewater producing industries etc.

For example; olive mill wastewaters (OMW) has a high pollution power with biological oxygen demand (BOD) values in the range of 89–100 g/l and chemical oxygen demand (COD) values in the range of 80–200 g/l. These values are around 200–400 times higher than those of a typical municipal sewage (Fadil et al., 2003).

Treatment of textile dye industry wastewater is highly complex due to the presence of color, toxicity, BOD, COD, turbidity, TDS, TSS, etc. Physical and/or chemical processes are employed for the treatment of dye wastewater. But these processes have some drawbacks. Alternatively, biological processes have received great attention in recent years for its efficiency and inexpensive. Microorganisms like bacteria, fungi and yeast are widely used for the decolorization of dye wastewater (Sathian et al., 2014).

Materials and methods

Characteristics of the inoculum used in the experiments

The inoculum was activated sludge biomass coming from municipal wastewater treatment plant. The experimental work for prepare of inoculum was carried out on bench scale SBRs made of Plexiglas vessel with a working volume of 3 litres and ports for effluent and sludge wastage. Air was provided using a glass diffuser, connected to an air pump. Feed addition and sludge wasting were achieved using peristaltic pumps. Digital timers connected to the reactors were used to automatically control reaction times, aeration and mixing. Agitation speed was 1,1 rpm. The diagram of the bench scale SBR system is depicted in Fig. 1. The cycle time of the reactors was kept constant at 14 h per day as shown in Fig. 2. Sludge was wasted at the end of the aerobic period and the effluent was withdrawn at the end of the settling period. The SBRs were fed with synthetic wastewater with the following composition (Table 1).

The SRT was 10 days and the operating F/M range was 0.342 and 0.786 mg COD / mg MLVSS day for R1 and R2, respectively. The reactor was operated at room temperature. The activated sludge obtained after this aeration process was used as inoculum in the experiments.

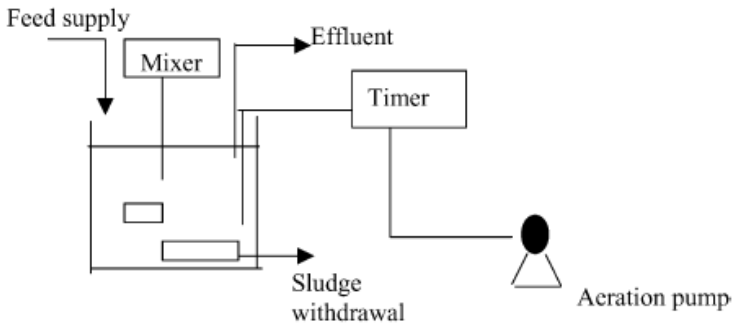

Fig. 1: Schematic diagram of the SBR used in this study (Sarioglu, 2005).

Feed	Aerobic		Settle
Mixing and influent pump	Mixing and aeration	Mixing only	No mixing, no aeration
Operating time (hours)			
4 hours	8 hours	1 hour	1 hour

Fig. 2: Operating stages of the 14 h SBR cycle.

Table 1: Synthetic influent composition (COD = 3000 mg/l, pH buffer 8.2) (Van den Broeck et al., 2009).

Component	Concentration (g/l)
$C_6H_{12}O_6$ (glucose)	2,550
NaCl	0,075
$CaCl_2.2H_2O$	0,075
$MgSO_4.7H_2O$	0,075
$FeCl_3$	0,015
$(NH_4)_2HPO_4$	0,583
K_2HPO_4	1,875

Batch experiments and experimental procedures

Original wastewater samples (IW) used as substrate were obtained from metal production plant. As IW does not contain microorganisms capable of aerobic degradation, a previous stage was necessary to acclimatize bacterial flora from activated sludge to this substrate. For this purpose, the reactor was inoculated with an activated sludge taken from a municipal wastewater treatment plant.

The batch aerobic experiments were carried out in 250 ml glass erlenmayer flasks with a working volume of 150 ml. Each of the flasks consisted of aerobic mixed culture to provide a sludge concentration of 3000 mg MLVSS / l. Two experimental runs were carried out in batch mode using

different initial substrate concentrations (3680 and 9000 mg COD / l in Runs 1–2, respectively) at the ratio of the initial substrate concentration to the initial biomass concentration So/Xo equal to 0,5 and 3,5 g COD / g MLVSS while equal to 1 ratio of synthetic wastewater to IW, respectively. Table 2 shows the operating conditions of the two runs (R1 and R2) performed during the experiments. A temperature controlled incubator was used at 35^{o}C for all experiments. The flasks were shaken at 150 rpm. Each experimental run was carried out in duplicate and the final results considered were the average values obtained.

Analytical methods

COD, pH, MLVSS, and bicarbonate alkalinity were measured according to standard methods. The COD concentrations were determined with closed reflux titrimetric method (APHA, 2005). The samples were centrifuged at 4000 rpm for 30 min before determining the concentrations of COD. 0.45 μm membrane filters were used to determine MLVSS concentration.

Table 2: Experimental conditions of aerobic batch study.

Stock		Volume (ml)	Resulting concentrations
Sludge	8790 mg MLVSS/l (R1) 13360 mg MLVSS/l (R2)	51,2 33	3000 mg MLVSS/l
Glucose (synthetic wastewater)	3000 mg COD/l (R1) 10500 mg COD/l (R2)	37,5 75	Desired composition
$NaHCO_3$	50 g/l (R1-R2)	15	5000 mg/l
IW	76000 mg COD/l (R1) 76000 mg COD/l (R2)	1,48 10,36	Desired composition
Total volume		150 ml (R1-R2)	

Results and discussion

Variation of the parameters evaluated as a function of time

Figs. 3-6 show the profiles of substrate concentration as COD, pH, and alkalinity in Runs 1-2, respectively. An increase in the initial substrate concentration not caused a decrease in the percentages of COD removals. Alkalinity and pH values increased with the aeration time in all experimental runs.

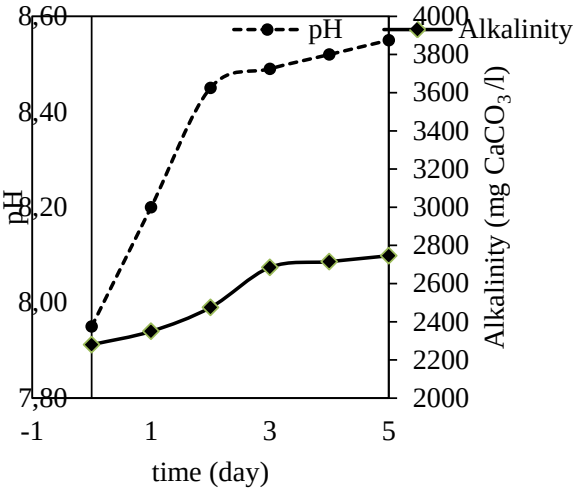

Fig. 3: Variation of pH and alkalinity during the operation time (R1)

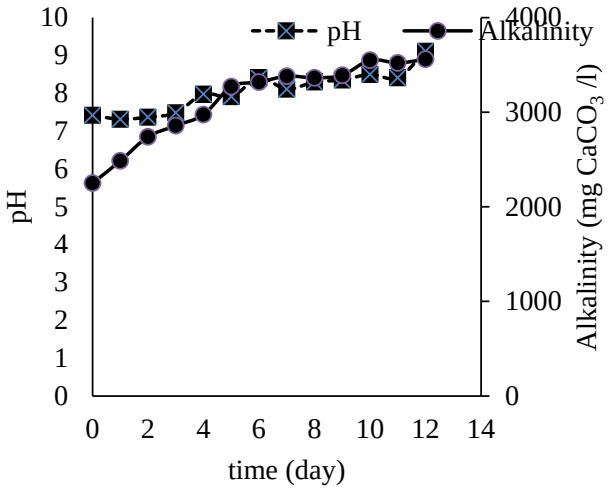

Fig. 4: Variation of pH and alkalinity during the operation time (R2)

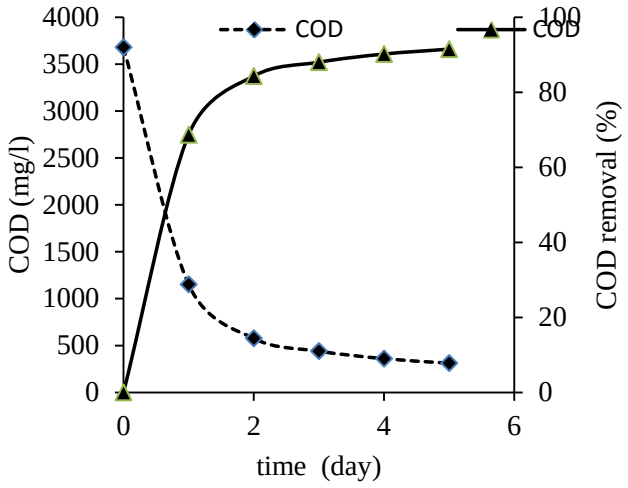

Fig. 5: COD removal using mixed culture during the operation time (R1)

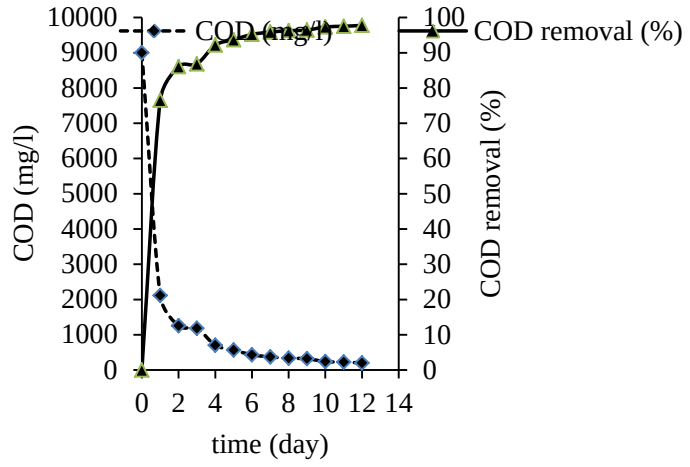

Fig. 6: COD removal using mixed culture during the operation time (R2)

The results of COD samples of the present study indicate removal efficiencies of 91,52% for 5h reaction time for R1, and 93,7% for 5h reaction time while 98% for 12h reaction time for R2.

Kinetics of organic matter removal

Based on experimental data, kinetic constants of substrate degradation were determined by using Eq. (1). A first order kinetic expression was often used to describe the biodegradation process (Durai et al., 2011).

$$dC/d_t = -k\,C \qquad (1)$$

where C is the substrate concentration (mg COD/L), t is the degradation time (min) and k is the biodegradation rate constant. First-order kinetic model was used to determine kinetic constants of COD degradation as shown in Figs. 7-8. Ln ($S_i/S_{o)}$ versus time were plotted to find out the kinetic data.

Figs 5-6 show the variation of COD versus the experimental time. The organic matter concentration decreased with time, following a logarithmic pattern, which is considered a classic first-order kinetic. The obtained values of R^2 confirmed that the first-order kinetic model was suitable to describe the degradation of organic matter in the reactor. In a first-order kinetic model, the substrate concentration at any aeration time may be expressed as follows Eq. (2) (Sa´nchez et al., 2007).

$$S= S_o [Exp – k_1\theta] \quad (2)$$

Figs. 7 and 8 show these plots for Run 1 and 2, respectively. A group of straight lines whose slopes were equivalent to k. Regression coefficients (R^2) were 0,894 and 0,944; values of the slopes obtained were 0,3083 and 0,2038 d^{-1} for Run 1 and 2, respectively. The low value of k obtained for the highest initial substrate concentration (Runs 1 and 2). The comparison of the experimental data and the theoretical ones obtained by Eq. (1) gave differences lower than 5 % in both cases.

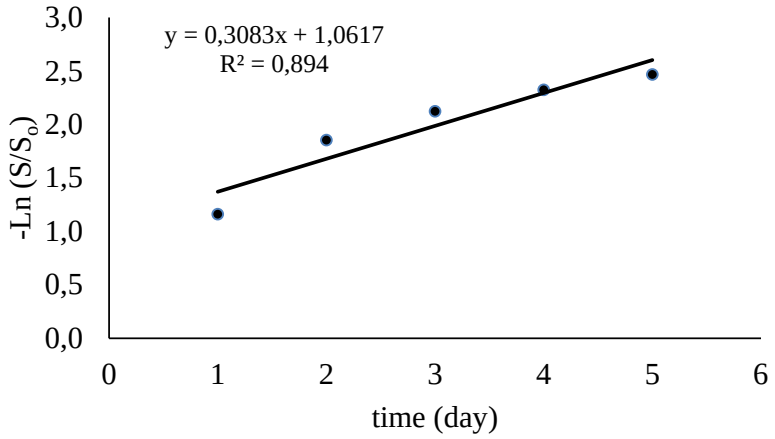

Fig. 7: Determination of the first-order kinetic constant for Run 1

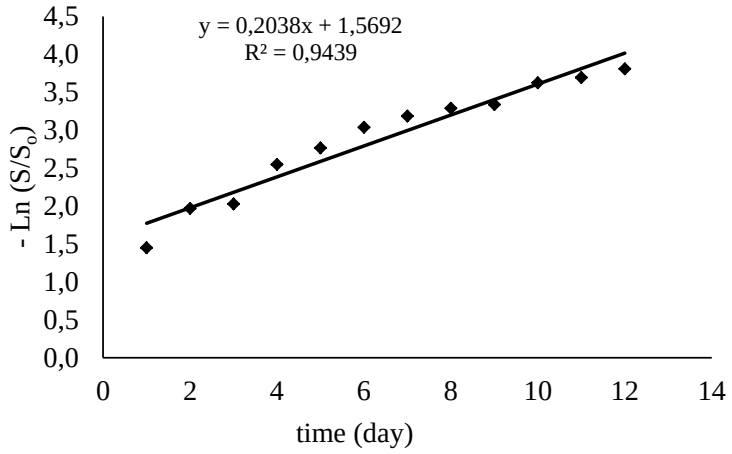

Fig. 8: Determination of the first-order kinetic constant for Run 2

Conclusion

The results of this study demonstrate that industrial wastewaters containing COD are biodegradable aerobically in batch mode. An increase in the initial substrate concentration not caused a decrease in COD removals at similar reaction times. Maximum COD removals of 91,52 % and 93,7 % were achieved after 5 day of reaction time for an influent substrate (COD) concentration of 3680 and 9000 mg l^{-1} (Runs 1 and 2).

The kinetic study was carried out using a first order based model and the degradation follows the first order system.

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